A R C H I V E S O F M E T A L L U R G Y A N D M A T E R I A L S
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SHORT ROUTE – LONG-TERM SUCCESS: INTEGRATED MINI-MILL SOLUTIONS BY MIDREX AND SMS DEMAG

KRÓTKA LINIA TECHNOLOGICZNA – DŁUGOTERMINOWE EFEKTY: PROJEKT ZINTEGROWANEJ MINIWALCOWNI FIRM MIDREX I SMS DEMAG

SMS Demag and Midrex Technologies formed a strategic alliance and have teamed up to offer an integrated mini-mill concept for the production of high-quality hot rolled coils based on direct reduced iron (DRI). The cooperation of the market leaders in the fields of direct reduction, electric steelmaking and combined continuous casting/hot rolling enables steelmakers to profit from the shortest route from iron ore to hot rolled coils (HRC). Customers benefit from unique and well-proven technology:

- MIDREX® Plant
- ARCCESS® EAF (electric arc furnace)
- CSP® technology (compact strip production)

The direct reduced iron produced by the MIDREX Plant features a high metallic iron content, but almost no nonferrous metal impurities which are undesired in steel. In combination with SMS Demag's clean-steel technology, it is possible to achieve ambitious metallurgical results and to reliably produce sophisticated steel grades. The optimally tuned plant components are designed for maximum energy-efficiency over the whole process route and hence result in a fast return-on-investment.
Keywords: Raw materials, direct reduction, electric steelmaking, mini-mill

Firmy SMS Demag i Midrex Technologies połączyły razem siły, wspólnie opracowały i przedstawiły projekt mini walcowni znajdujących zastosowania w produkcji wysokiej jakości gorąco walcowanych kręgów, w oparciu o proces redukcji bezpośredniej żelaza (DRI). Współpraca liderów z dziedziny redukcji bezpośredniej, elektrometalurgii oraz nowoczesnych metod ciągłego odlewania/walcowania na gorąco pozwoliła metalurgom uzyskać korzyści ze skróconej linii technologicznej od rudy żelaza do kręgów walcowanych na gorąco (HRC). Uzyskano korzyści z unikalnej i dobrze sprawdzonej technologii:

- MIDREX® Plant,
- ARCCESS® EAF (piece łukowe),
- CSP® technology (produkcja kompaktowa).

W bezpośrednio zredukowanym żelazie według technologii w MIDREX Plant uzyskuje się wysoką zawartość żelaza metalicznego, przy praktycznie braku zawartości wtrąceń nieżelaznych, niepożądanych w stali. W połączeniu z technologią „clean-steel" firmy SMS Demag możliwe jest osiągnięcie bardzo dobrych rezultatów w procesach elektrometalurgicznych oraz produkcja specjalnych gatunków stali. Głównym celem optymalizacji jest uzyskanie jak najwyższej wydajności energetycznej podczas całego procesu, aby uzyskać szybki zwrot kosztów poniesionych na inwestycje.

1. Introduction

In June 2007, Midrex Technologies, Inc., Kobe Steel, Ltd. and SMS Demag AG signed an alliance agreement for the marketing and implementation of projects based on the MIDREX® Direct Reduction Process and SMS Demag's ARCCESS® EAF and Compact Strip Production (CSP®) Technologies. This will provide for an integrated steelmaking facility from iron ore through hot strip and is not only the shortest production route, but also ensures low costs and high quality. This cooperation agreement matches the expertise of Midrex and Kobe Steel in supplying the world's leading direct reduction technology with the global capabilities of the SMS group.

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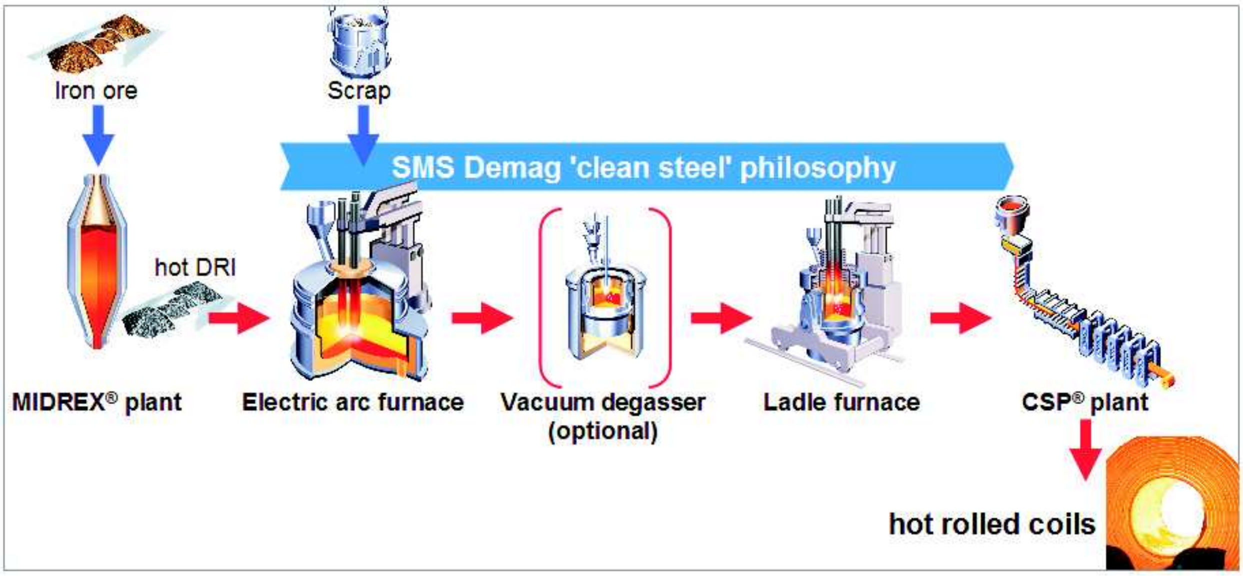

Fig. 1. Conceptual flowsheet for the integrated mini-mill concept

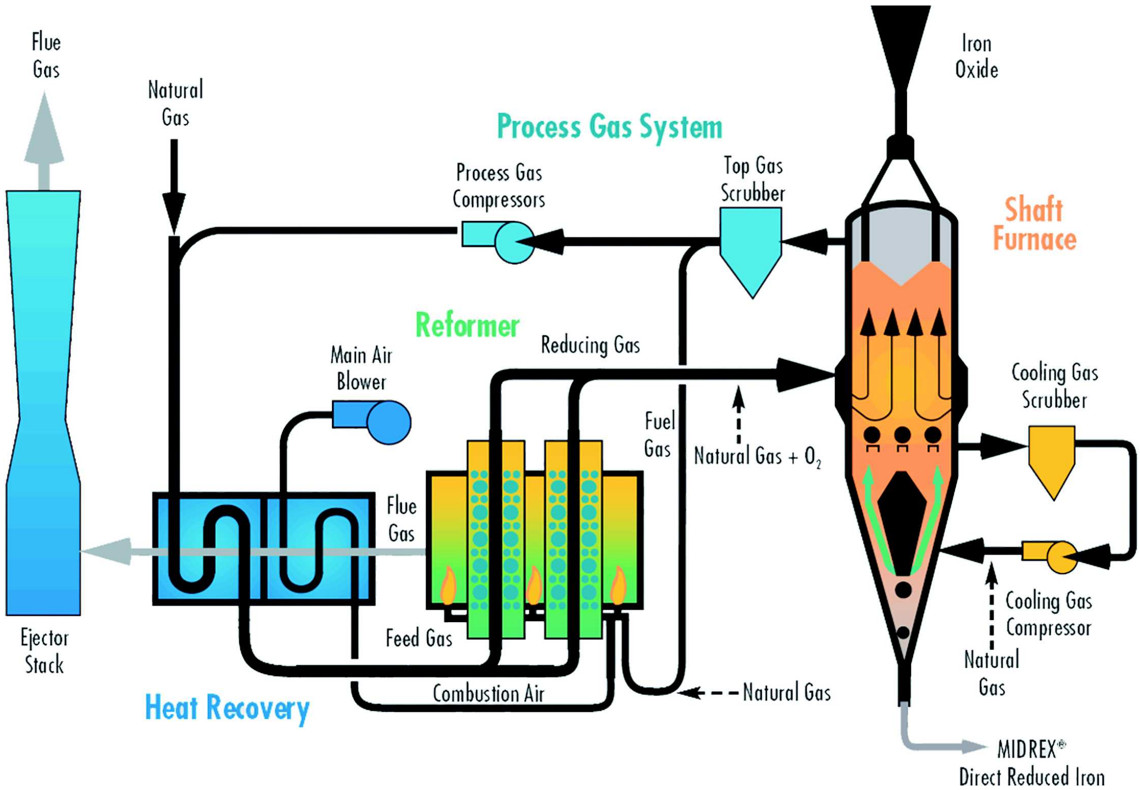

Fig. 2. Schematic representation of the MIDREX® Process for the production of DRI

2. Midrex® direct reduction process

The key components of a MIDREX® Plant are a shaft furnace, a reformer as well as systems for gas cleaning and heat recovery. Since iron occurs in nature in the form of oxide compounds, the goal of the MIDREX Process is to reduce the iron ore (that is, remove oxygen). This is done in a countercurrent process using natural gas as the reducing agent.

For this purpose, the shaft furnace is continuously charged with iron ore. Inside the furnace, the charged material moves from the top downwards while a reducing gas, which consists mostly of hydrogen and carbon monoxide, flows in opposite direction, i.e. from the bottom upwards. The product is solid DRI, sometimes called sponge iron.

In the reformer, the cleaned process gas of the furnace is blended with fresh natural gas, then heated and converted to hydrogen and carbon monoxide by means of a catalytic reaction. The hot reformed gas is sent directly to the shaft furnace.

Depending on the type of use and the raw material logistics, DRI can be briquetted in the hot state (HBI = Hot Briquetted Iron) or is cooled (cold DRI) before it is charged into the EAF or a Conarc®.

The DRI produced by the MIDREX Process features a high metallurgical iron content, but almost no nonferrous metal impurities which are undesired in steel. Nearly 60% of the world's direct reduced iron (DRI) is produced by means of the MIDREX Process.

In combination with SMS Demag's Clean-Steel technology it is possible to achieve ambitious metallurgical results and to reliably produce sophisticated steel grades.

Chemical processes

Reduction $Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

Carburization $3Fe + CO + H_2 \rightarrow Fe_3C + H_2O$

$3Fe + CH_4 \rightarrow Fe_3C + 2H_2$

Reforming $CH_4 + CO_2 \rightarrow 2CO + 2H_2$

$CH_4 + H_2O \rightarrow CO + 3H_2$

3. Arccess technology

ARCCESS® EAF technology utilizes SMS Demag's superior design capabilities and its operating know-how. ARCCESS® stands for the customer's success in electric arc steelmaking. The characteristic feature of the ARCCESS® furnace is its consequently optimized use of electric energy and burner/oxygen injection technology which together yield a high productivity at low production cost. The design features include a logistically optimized plant layout, modularized furnace concept, customized furnace shell, and optimized panel design and construction. Advanced process know-how comprises productivity maximization by injection, combustion, and oxygen technologies; and optimized energy utilization via superior electrode control systems and a novel slag foaming practice.

The technology includes a novel process control system known as X MELT® FEOS, that was developed in cooperation between SMS Demag and the University of the Federal Armed Forces, Hamburg, Germany. FEOS stands for **F**urnace **E**nergy **O**ptimizing **S**ystem and it represents an integrated, closed-loop solution for all materials and energy flows of the electric arc furnace.

The system consists of three hardware elements and its implemented software. Using a PLC as exclusive interface it's easy to integrate in an existing furnace environment. The system contains controls for the transformer tap, the reactor tap and the impedance setpoint. Further controls for burners, postcombustion-oxygen injectors, fine-coal injectors and DRI feeding are implemented. Additionally, the industrial PC provides an HMI (human machine interface) for process engineer's use allowing for process analysis, adjustment and optimisation. For trial and easy adjustment of the control parameters an offline-version is implemented. The offline-version uses previous process data to simulate the behaviour of the EAF.

The ARCCESS system minimizes the total cost of ownership (TCO) and provides outstanding value. Direct investment in the EAF is optimized by cost-effective design, accelerated lead time and commissioning and the shortest ramp-up time, including performance guarantees. Operating costs are reduced through maximized yield, minimized tap-to-tap time, the lowest energy consumption, reduced downtime and maximized plant availability.

TABLE

ARCCESS Installations

Start up	Plant	Location	EAF Capacity
2010	Peiner Träger GmbH	Germany	125 t
2010	OAO Kemz (Maxi Group)	Russia	120 t
2009	OAO Taganrog Metallurgical Works	Russia	135 t
2009	Forpost Energu	Russia	120 t
2009	Pervouralsky New Pipe Works (PNTZ)	Russia	120 t
2008	OAO Seversky Tube Works	Russia	135 t
2006	Celsa Manufacturing UK	Wales	140 t
2005	Nucor Texas	USA	80 t
2001	Kaptan Demir Celik	Turkey	100 t

4. Hot charging

Both steelmaking costs and CO_2 emissions are significantly reduced by direct charging of hot DRI to the EAF. Midrex has now developed three options for hot charging DRI to the EAF: HOTLINK®, a hot transport conveyor, and hot transport vessels. The options are shown in Figure 3 and all three of these configurations have been started up or are under construction.

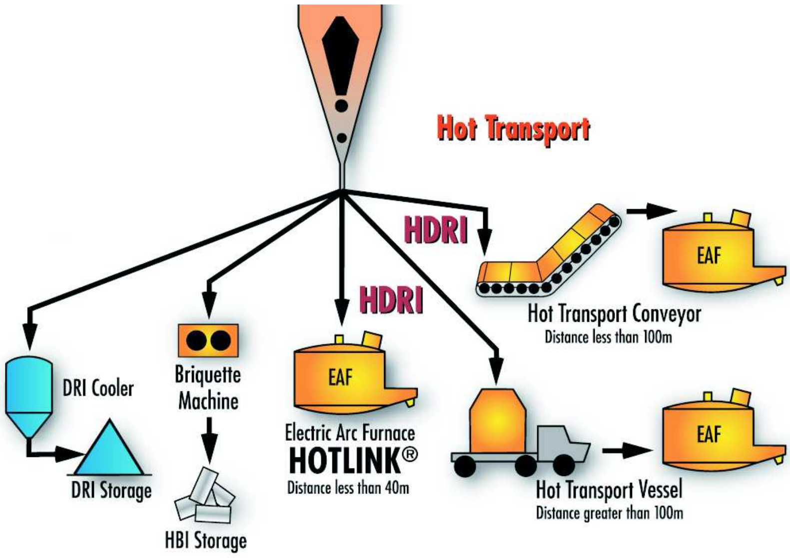

Fig. 3. Different discharge options

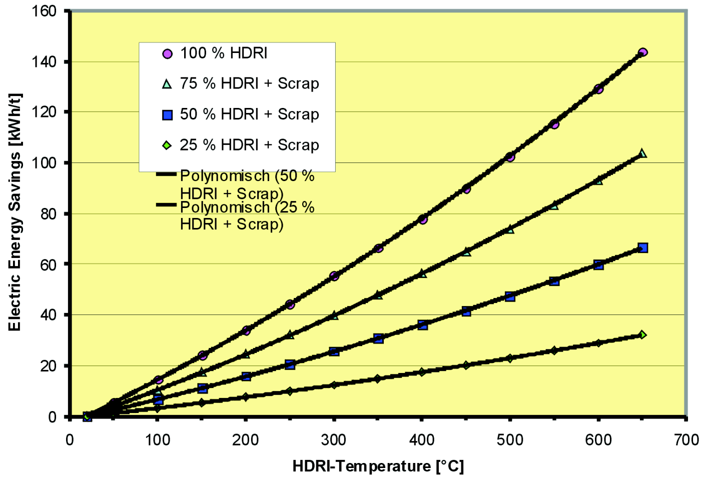

Fig. 4. Electric energy savings as function of hot DRI temperature at different hot DRI ratios

Each of these options provides the necessary flexibility for the steelmaker. For a greenfield plant in which the meltshop can be located adjacent to the MIDREX Plant, HOTLINK using predominantly gravity feed can be the best solution because of its simplicity. If the meltshop is less than 100 meters from the MIDREX® Shaft Furnace, a hot conveyor is a possibility. For locations where the meltshop is more than 100 meters from the shaft furnace, hot transport vessels are used. These vessels can be transported by rail or truck. In all three options, the DRI is charged to the EAF at 600-700°C.

Charging 100% hot DRI into the EAF will reduce electric energy consumption about 20 kWh/t of liquid steel for each 100°C increase of charge temperature. Thus, hot DRI feeding at a temperature of 650°C provides energy savings of approximately 140 kWh/t.

Regarding environmental sustainability the process route of natural gas based DR-EAF creates lower CO_2 emissions than an integrated BF/BOF route [1; 2], charging hot DRI into the EAF improves this balance all the more.

5. CSP

Compact Strip Production (CSP®) Technology was developed by SMS Demag in the 1980s and commercialized at Nucor Crawfordsville, USA, in 1989. CSP is a continuous process during which liquid steel is directly processed into thin or ultra-thin hot strip, 1.0 mm or thinner and in semi-endless operation with slab lengths of more than 260 meters.

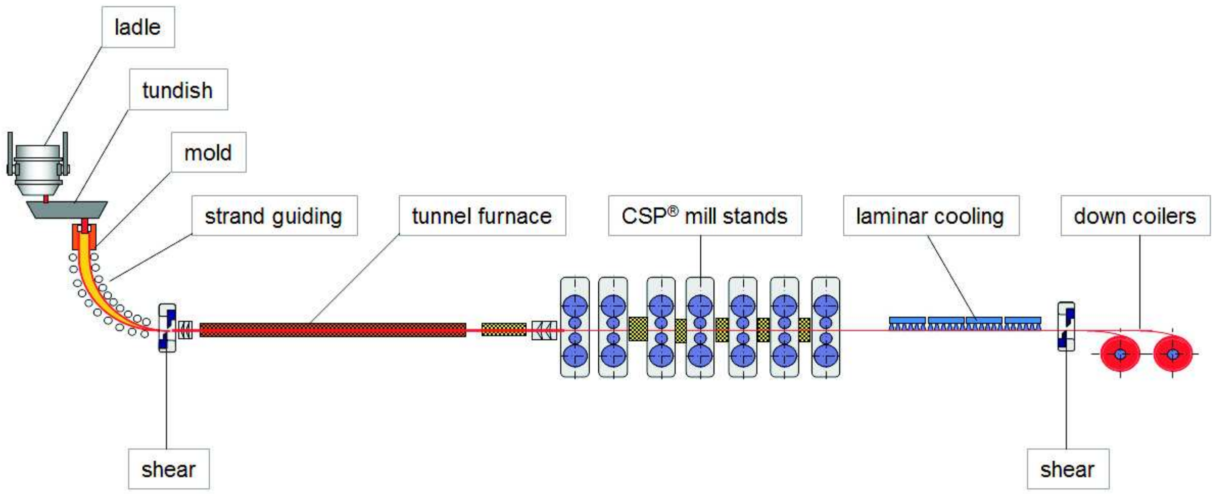

Fig. 5. Schematic flowsheet of a CSP® plant

The key to its success is state-of-the-art technology that keeps the steel within a precisely defined window of temperature. Included in the package are the patented CSP® mold with hydraulic oscillation, LCR liquid core reduction, the CVC plus® technology applied during the rolling process, as well as process models for strip flatness and thickness control. Their smooth meshing due to X-Pact® automation provides first-class strip qualities.

The economics of the CSP® Process compared to a conventional integrated hot strip mill can be outstanding. Savings of up to 70 percent in energy costs, 25 percent in production cost and 50 percent in investment are possible.

Today there are 28 facilities worldwide, including North America, Europe, Africa, and Asia, with a total capacity of approx. 50 Mtpy. The CSP® technology today accounts for around 10 percent of total world production of hot-rolled flat products. The actual production figures of most facilities exceed their design capacities.

Since the introduction of CSP® technology, SMS Demag and its clients have steadily reduced the minimum final strip thicknesses attainable during hot rolling. Today, stable rolling of strips down to 1 mm is routine – as demonstrated by the 28 CSP® references. The latest milestone reached was the production of 0.78-mm-thin hot strip in semi-endless operation at Lianyuan Iron & Steel Group Co. Ltd. (Lysteel), PR China.

As a rule, CSP® plants consist of:

- Ladle turret or turrets
- Tundish treatment facilities
- Oscillating CSP mold
- Strand guide
- Withdrawal and straightening units
- Pendulum shear
- CSP® soaking furnace (with swivel ferry for two strands)
- Hydraulic shear, descaler and roller side guides
- Multi-stand CSP® rolling mill
- Laminar cooling section
- Coiler station
- Other transport and marking devices

The product mix of the first CSP® plant at Nucor Crawfordsville during the initial operation period consisted only of simple steel grades such as low and medium carbon. In the course of its continuous development, the advantage of the CSP® technology began to be fully realized. The high temperature homogeneity allows reliable production of strips of 1.0 mm and below. The product mix was continuously expanded and now includes micro alloyed grades and silicon grades, as well as ferritic stainless steel. CSP® technology is also used to produce advanced high-strength steels for the automotive industry, including dual phase and TRIP steels. Figure 4 shows the advancements in production of higher grade steels using CSP®, which were driven by needs for enhanced mechanical properties and surface requirements

SMS Demag is now developing even better steels for automotive uses. One important group is HSLA for internal parts of car bodies. A CSP® plant in the USA is producing nearly 600,000 tpy for this application. The production of hot-rolled DP- and TRIP grades with excellent mechanical properties was introduced in recent years in several CSP® plants. Also, stainless steel (ferritic grades) are used for automotive parts, like catalytic converters. New CSP® plants intend to produce a high share of multiphase steel and material for exposed parts including IF grades via the EAF/ladle furnace/vacuum degassing route, using a high percentage of virgin material in the charge mix. The tendency for the future is that more and more automotive grades will be produced by CSP® technology.

6. Combining MIDREX and SMS demag technologies

The combination of the MIDREX Process, ARCCESS and CSP® will provide steelmakers reduced energy consumption, lower production costs and efficient production of high quality hot strip. This can be achieved through:

- Efficient production of DRI with low specific energy consumption
- Charging DRI to the EAF at a temperatures of 600°C or higher
- ARCCESS EAF with advanced equipment, process control and operating practices
- Process-inherent benefits through direct rolling of hot thin slabs by the CSP process.

Thanks to the high iron and low residual metals contents of the DRI produced by the MIDREX Process, even highly demanding steel grades can be produced by this route. The alliance of the market leaders in the fields of direct reduction, EAF steelmaking and thin-slab technology provides technical, commercial and organizational benefits for the world steel industry. The combined experience of Midrex, Kobe Steel and SMS Demag in project implementation, process development, metallurgy and innovation provides an outstanding team.

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